[redacted]

MR June 1943

[redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

12 DEC 1947

WARTIME REPORT

ORIGINALLY ISSUED
June 1943 as
Memorandum Report

TANK TESTS OF A 1/8-SIZE DYNAMIC MODEL OF THE PB2Y-3 AIRPLANE WITH INCREASED POWER - NACA MODEL 131

By Joe W. Bell and Robert F. Havens

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NACA

WASHINGTON

NACA LIBRARY
LANGLEY MEMORIAL AERONAUTICAL
LABORATORY
Langley Field, Va.

NACA WARTIME REPORTS are reprints of papers originally issued to provide rapid distribution of advance research results to an authorized group requiring them for the war effort. They were previously held under a security status but are now unclassified. Some of these reports were not technically edited. All have been reproduced without change in order to expedite general distribution.

NASA Technical Library
3 1176 01403 5746

MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

TANK TESTS OF A 1/8-SIZE DYNAMIC MODEL OF THE PB2Y-3 AIRPLANE WITH INCREASED POWER - NACA MODEL 131

By Joe W. Bell and Robert F. Havens

INTRODUCTION

The Consolidated Aircraft Corporation has undertaken the installation of 1300-horsepower engines in the PB2Y-3 airplane in place of the present 1200-horsepower engines. With this additional power, the operation of the airplane is expected to include flights at a gross load of 76,000 pounds. Since earlier tests of a 1/8-size dynamic model of the PB2Y-3 airplane with simulated jet motors (reference 1) indicated that the airplane would be unstable on the water at loads of 76,000 pounds, further tests of the model were necessary.

The stability and spray tests described herein were made to determine the performance of the model on the water when tested at both the present and the projected conditions of gross load and engine power. The data obtained therefore cover a range of operating conditions, such that the present performance of the PB2Y-3 airplane can be directly compared with results of the model tests. Such a comparison affords a basis for the proper interpretation of the model data at higher gross weights and assures a more accurate estimate of the performance of the PB2Y-3 airplane when equipped with the larger engines.

This investigation was part of the work requested by the Bureau of Aeronautics, Navy Department, on May 5, 1941, and was conducted during February and March 1943. The Consolidated Aircraft Corporation was represented by Messrs. E. G. Stout and H. E. Brooke. L-688

DESCRIPTION OF MODEL

The construction and special features of this model, designated NACA model 131, are described in reference 2. Figure 1 shows the general arrangement of model 131 and gives important dimensions.

The locations and dimensions of the ventilating ducts of the model are shown in figure 2. These ducts were part of a ventilation system which had been installed in the model for use in earlier tests and were a convenient approximation to those used on the full-size airplane.

The wing was of normal area and was equipped with partial-span, inboard flaps and leading-edge slats. Each of the four nacelles housed an alternating-current induction motor which was directly connected to a three-blade metal propeller, $19\frac{1}{2}$ inches in diameter.

The angular setting of the propeller blades and speed of rotation which would produce scale take-off thrust were determined from the propeller test curves given in reference 2. A constant blade angle of 8° at 0.75 radius was maintained and the speed of rotation changed to simulate changes in engine power. The propellers of the model turned at 6200 rpm to reproduce the scale take-off thrust of the airplane equipped with 1200-horsepower engines and at 7000 rpm to reproduce the increased take-off thrust provided by 1800-horsepower engines.

Provision was made on the model for the interchange of geometrically similar elevators and elevators having a 20-percent increase in chord, either of which could be controlled by means of a control stick mounted on the carriage.

The pitching moment of inertia of model 131, when balanced with the pivot at 28 percent of the mean aerodynamic chord, was found to be 15.9 slug-feet^2. This value agrees closely with the scale moment of inertia, 15.3 slug-feet^2, given in reference 2 for a gross load of 76,000 pounds.

APPARATUS AND PROCEDURE

General

This investigation was made in NACA tank no. 1 (reference 3) and consisted of:

(1) Aerodynamic tests to develop a configuration of the aerodynamic surfaces having characteristics comparable to predetermined wind-tunnel results.

(2) Hydrodynamic tests to determine the stability and spray characteristics of the model during accelerated runs.

Aerodynamic Tests

The aerodynamic tests were made in the usual manner with the model pivoted about a point at 25 percent of the mean aerodynamic chord and suspended just above the water under the main carriage. The model was towed at a constant speed of approximately 42.5 feet per second, while lift and trimming forces were measured with ring dynamometers. All data were obtained at the mid-length of the tank.

Power-off tests were made with the propellers removed from the model.

Since the airspeed just ahead of the model was 5 percent greater than the speed of the carriage, all tests simulated normal full-scale operation in a light head wind. Nevertheless, values of lift and trimming-moment coefficients were computed from true carriage speed rather than from true airspeed.

Hydrodynamic Tests

These tests were made in the manner described in reference 4, by towing the model under the main carriage at a constant rate of acceleration in order to determine the variation of trim with speed at several elevator settings. The greater part of the tests were made at an acceleration of 1 foot per second per second, which is the normal acceleration used.

Higher accelerations were used during several tests, however, to determine the effects of a more rapid take-off run. The model was towed from various positions of the center of gravity at consecutive accelerations of 1, 2, and 3 feet per second per second. Records of the variation of trim with speed were obtained by means of a correlation of motion pictures of the trim scale readings with records of distance and time. At the same time motion pictures of the bow of the model were taken to show the height and volume of the bow spray during different accelerations. These pictures were made at 64 frames per second when the gross weight of the model was 143 pounds (76,000 pounds full size) and the propellers were turning at 7000 rpm.

The motors were turned on during the normal accelerated runs at a speed of approximately 15 feet per second in order to avoid the destructive effects of spray. Since hump speed was about 17.5 feet per second, the effects of power were applied throughout the critical planing range.

RESULTS AND DISCUSSION

Aerodynamic Tests

The aerodynamic characteristics of model 131 with several configurations of the aerodynamic surfaces and different amounts of power are presented in the figures listed in the following table:

Figure no.	Propeller rpm	Stabilizer setting relative to base line (deg)	Elevator chord	Flap deflection (deg)
3	0	-3	Normal	20
4	0	-3	Normal	40
5	0	-3	Increased	20
	0	2	---do----	20
6	7000	2	---do----	20
	7000	2	---do----	40
7	6200	-3	---do----	20
	6200	-3	---do----	40
8	7000	-3	---do----	20
	7000	-3	---do----	40
9	0	-3	Normal	20
	0	-3	Increased	20
10	0	-3	---do----	20
	6200	-3	---do----	20
	7000	-3	---do----	20

Lift and trimming-moment coefficients are referred to standard air density, normal wing area, and the speed of the carriage.

Figures 3 and 4 compare the power-off aerodynamic characteristics of the final configuration of the model, as tested on the water, with wind-tunnel results furnished by the representatives of the contractor. The elevator effectiveness of the tank model with normal chord elevators and the stabilizer set at -3° relative to the base line was slightly greater than the wind-tunnel model, except at stall. Excellent agreement is shown for the values of the maximum lift coefficients and for the slopes of the lift and moment curves.

The effect of changing the stabilizer setting from -3° to 2° relative to the base line of the model is shown in figure 5. Results of tests with increased chord elevators are given in this figure, as well as in figures 6, 7, and 8 which are plots of aerodynamic tests with power. These elevators had been used on the model during previous tests under the auxiliary carriage. Since good agreement with power-off, wind-tunnel data was obtained in the present tests with scale elevators (figs. 3 and 4), the greater lift and control moment afforded by increased chord elevators (shown in fig. 9) were not considered necessary.

The effects of running propellers on the aerodynamic characteristics are shown in figure 10. There are four principal effects: (1) greatly increased lift, (2) an increase in the slope of the lift curve, (3) increased elevator effectiveness, and (4) decreased static pitching stability. Figure 10 also gives the results of wind-tunnel tests with power, in which are included the changes in lift and trimming moment due to ground effect. This figure shows discrepancies between tank and wind-tunnel data which do not occur in the power-off condition. A comparison of the conditions under which both tests were made, however, partially accounts for these differences. Tank tests are made at relatively low speeds with scale take-off thrust, while wind-tunnel tests are usually made at high speeds in order to duplicate a specific steady-flight condition. Since the moment caused by thrust and the trimming moment caused by other aerodynamic forces do not vary in the same manner with speed, the negative increments of trimming-moment coefficient caused by power in tank tests usually are much greater than that resulting from wind-tunnel tests at higher speeds. This is shown in figure 10 to be the case for the present tests. Furthermore, ground-effect corrections applied to wind-tunnel test curves are subject to inaccuracies, especially when consideration must be made of the effects of slipstream.

Because of the possibility of inaccuracies in ground-effect corrections together with the difference in thrust-moment coefficient at different speeds, the method used for correlation of tank and wind-tunnel results was the reproduction of the lift and trimming-moment coefficient in the power-off condition.

Hydrodynamic Tests

The following table is an index to the hydrodynamic tests made at the normal acceleration and includes a partial list of the figures in which test results are plotted:

Conditions of the test					Index to figures		
Model			Full size		Variation of trim with speed	Max. ampl. of porp. against pos. c.g.	Limits of stable pos. of c.g. against load
Load (lb)	Rpm	Flaps (deg)	Horse-power per engine	Load (lb)			
143.0	6200	20	1200	76,000	11(a)		
140.0	6200	20	1200	72,000	11(b)	12	13
135.3	6200	20	1200	70,000	11(c)		
148.0	7000	20	1300	76,000	14(a)		
140.0				72,000	14(b)	15	16
135.8				70,000	14(c)		
143.0	7000	0	1800	76,000	18(a)	19	
135.3				70,000	18(b)		
148.0	7000	40	1800	76,000	20(a)	21	
135.3				70,000	20(b)		

<u>Effect of gross load with normal engine power, flaps 20°</u>. - Curves of the variation of trim with speed at all of the gross loads tested with normal power (6200 rpm) are given in figure 11. In nearly all cases, at aft locations of the center of gravity with up elevators, the model took off during divergent upper-limit porpoising. The amplitude of porpoising just before take-off at aft positions of the center of gravity has been plotted in figure 12, together with the maximum amplitude

of lower-limit porpoising at forward positions of the center of gravity. Figure 13, which is a summary of figures 11 and 12, shows the small effect increased load had upon the stable range of the positions of the center of gravity, considering the allowable magnitude of porpoising amplitude to be 2°. The stable range decreased from approximately 5.8-percent mean aerodynamic chord at a gross load of 70,000 pounds to 5-percent mean aerodynamic chord at 76,000 pounds when determined with elevator settings of 0° and -20°. The determination of the range of stable positions of the center of gravity, however, depends greatly on elevator setting, as is shown in figure 13.

<u>Effect of gross load with increased engine power, flaps 20°</u>. - The results of accelerated runs with increased power (7000 rpm) at three gross loads are plotted in figures 14 and 15 and summarized in figure 16. A comparison of figure 14 with figure 11 (normal power) shows the decreased trim produced by increased propeller thrust. The range of stable locations of the center of gravity shown in figure 16 was 4-percent mean aerodynamic chord at a gross load of 70,000 pounds and 3-percent of the mean aerodynamic chord at 76,000 pounds.

<u>Effect of increased load and power with flaps at 20°</u>. - Figure 17 shows that a change in operating conditions from a gross load of 70,000 pounds with a propeller speed of 6200 rpm

to a gross load of 76,000 pounds with a propeller speed of 7000 rpm has little effect on the aft limit of the center of gravity (about 38-percent mean aerodynamic chord in both cases) but moves the forward limit from 32-percent mean aerodynamic chord to 35-percent mean aerodynamic chord. Although these limits may not be in exact agreement with those experienced in the operation of the full-size airplane, the change in limits is believed to be indicative of the change that will result from increasing the power and the gross load of the airplane. The increase in power and gross weight appears to require a forward movement of the step for stability at normal positions of the center of gravity.

The bow spray was particularly objectionable with increased load and power. Water rose vertically ahead of the bow until the model obtained a speed of about 10 feet per second (17 knots full size). Large amounts of spray which entered the inboard propeller disks were thrown to the outboard propellers and over the wing throughout a speed range from 12 to 23 knots (full size).

Effect of deflection of flaps on stability. - Hydrodynamic tests were also made to determine the limits for stable positions of the center of gravity with flaps set at 0° and at 40°. Curves of the variation of trim with speed (figs. 18 and 20) are cross-plotted in figures 19 and 21 to show the maximum amplitude of porpoising at a propeller speed of 7000 rpm. Figure 22 shows the effect of the deflection of flaps on the range of stable positions of the center of gravity. A greater change in stability characteristics resulted from changing the deflection of the flaps from 0° to 20° than from 20° to 40°. The effect of deflecting the flaps 40° from the retracted position was to decrease the range of stable locations of the center of gravity by approximately 2.5 percent of the mean aerodynamic chord and to move the midpoint of the stable range aft by about 13-percent mean aerodynamic chord.

Effect of acceleration on stability and spray, flaps 20°. - An indication of the effect of acceleration on the magnitude of porpoising and the formation of bow spray was obtained by towing the model at accelerations of 1, 2, and 3 feet per second^2, with the propellers turning 7000 rpm. Plots of the variation of trim with speed and acceleration at several loads and several locations of the center of gravity are given in figure 23. This figure shows that porpoising occurred within the same range of speed at all accelerations and that the frequency of an average porpoising cycle was not greatly changed by acceleration. The variations in acceleration which occurred during the runs of figure 23 were due to the difficulty of control of the speed of the carriage. Cross plots of maximum amplitude of porpoising against acceleration, given in figure 24 show that the amplitude of porpoising was decreased by the use of higher accelerations. In view of this trend, the inconsistent results obtained in run A and run B (fig. 23) show that other considerations such as waves in the tank, small deflections of the elevator, small changes in the balance of the model, and inconsistent application of power can cause effects large enough to obscure the effects of acceleration. It is believed, however, that a more precise but less conservative determination of the stable limits of the location of the center of gravity would be obtained by model tests in which the average full-scale acceleration was approximately reproduced.

Motion pictures of model 131, taken during runs at the consecutively higher accelerations of 1, 2, and 3 feet per second per second indicate that acceleration has little effect on the formation and distribution of spray at a gross load of 76,000 pounds full scale. Large amounts of spray entered the propeller disks in all cases, but the excessive spray lasts for a shorter time, of course, with the higher accelerations.

CONCLUDING REMARKS

Tests of model 131 with propellers turning at 6200 rpm simulated operation of the PB2Y-3 airplane equipped with engines of 1200 horsepower, while tests with the propellers of the model turning at 7200 rpm simulated operation of a modified PB2Y-3 airplane with engines of 1800 horsepower. The results of these tests can be summarized as follows:

1. The effect of gross load on the range of stable positions of the center of gravity at both propeller speeds (6200 and 7000 rpm) was small for the gross loads tested. The range was decreased approximately 1-percent mean aerodynamic chord in tests with a flap deflection of 20° by increasing the load from 70,000 pounds to 76,000 pounds full size.

2. Increased power and load had little effect on the aft limit of stable range of locations of the center of gravity but moved the forward limit aft about 3 percent. With 20° flaps, at a gross load of 135.8 pounds (70,000 pounds full size) and a propeller speed of 6200 rpm, the forward limit determined with neutral elevators occurred at 32-percent mean aerodynamic chord, while the aft limit determined with -20° elevators occurred at 38-percent mean aerodynamic chord. At a gross load of 148 pounds (76,000 pounds full size) and a propeller speed of 7000 rpm, the forward and aft limits occurred at 35-percent and 38-percent mean aerodynamic chord, respectively. The possibility of low-angle porpoising at normal positions of the center of gravity is thereby increased unless the step is moved forward.

3. Deflection of the flaps from 0° to 20° produced a greater aft displacement of the range of stable locations of the center of gravity than was produced by the deflection

of the flaps from 20° to 40°. The stable range was decreased about 2.5-percent mean aerodynamic chord and moved aft 13-percent mean aerodynamic chord by deflecting the flaps from 0° to 40°.

4. Records taken when the model was towed at accelerations of approximately 1, 2, and 3 feet per second per second show that the maximum amplitude of porpoising of a dynamic model is decreased when the acceleration during take-off is increased. At forward locations of the center of gravity, the maximum amplitude of porpoising obtained at the normal rate of acceleration (1 foot per second per second) was decreased by as much as 40 percent when test runs were made at 3 feet per second per second.

5. Excessive amounts of water and spray came in contact with the inboard and the outboard propellers at gross loads of both 70,000 pounds and 76,000 pounds. Variations in the acceleration of take-off had little effect on the form and

distribution of bow spray. However, the effects of spray can be minimized by rapid acceleration through the critical speed range.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 9, 1943

REFERENCES

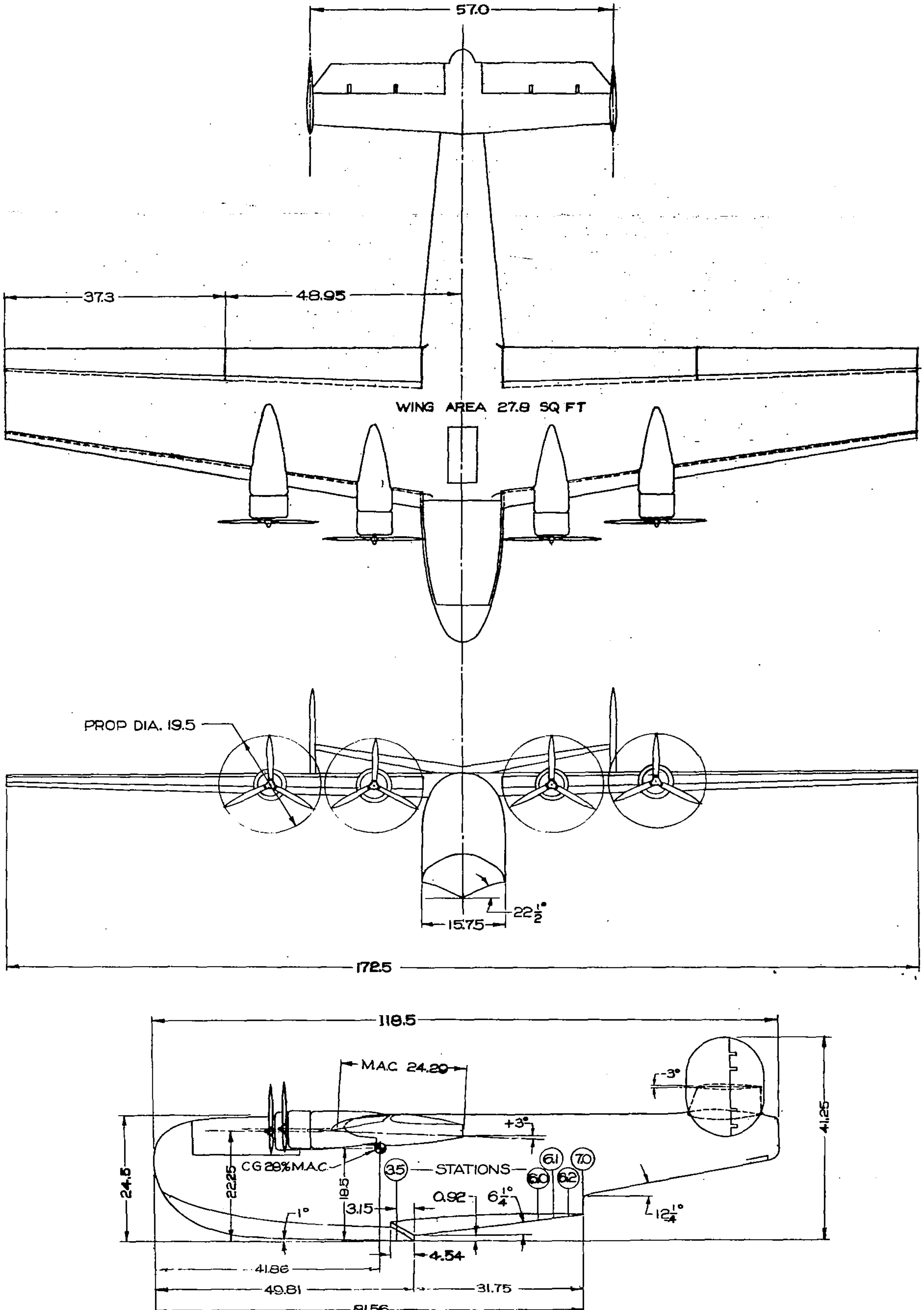
1. Bell, Joe W., and Havens, Robert F.: Tank Tests of a 1/8-Size Dynamic Model of the PB2Y-3 Airplane with Simulated Jet Motors - NACA Models 131J, 131J-1, and 131J-2. NACA MR, June 8, 1943.

2. Brooke, H. E.: Detailed Specification, PB2Y-3 - 1/8 Scale Powered Dynamic Model. Rep. No. ZH-29-008, Consolidated Aircraft Corp., Jan. 1942.

3. Truscott, Starr: The Enlarged N.A.C.A. Tank, and Some of Its Work. NACA TM No. 918, 1939.

4. Olson, Roland E., and Land, Norman S.: Methods Used in the NACA Tank for the Investigation of the Longitudinal-Stability Characteristics of Models of Flying Boats. NACA Rep. No. 753, 1943.

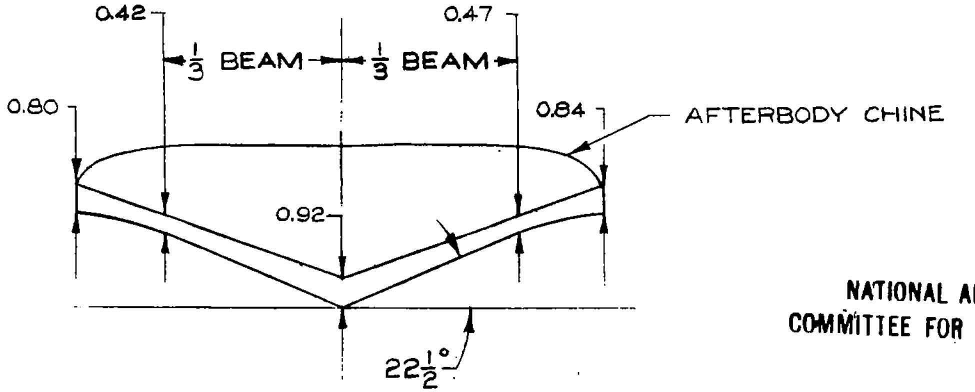
L-688



NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

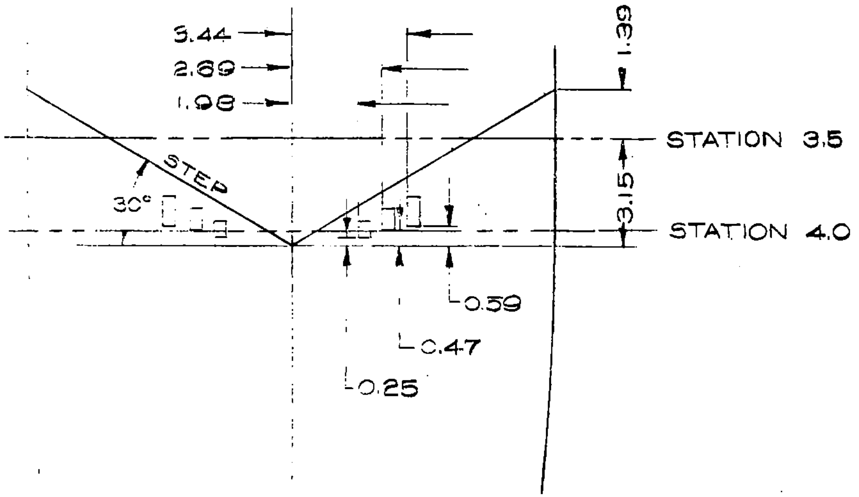
FIGURE 1.- GENERAL ARRANGEMENT, NACA MODEL 131.

ALL DIMENSIONS
IN INCHES



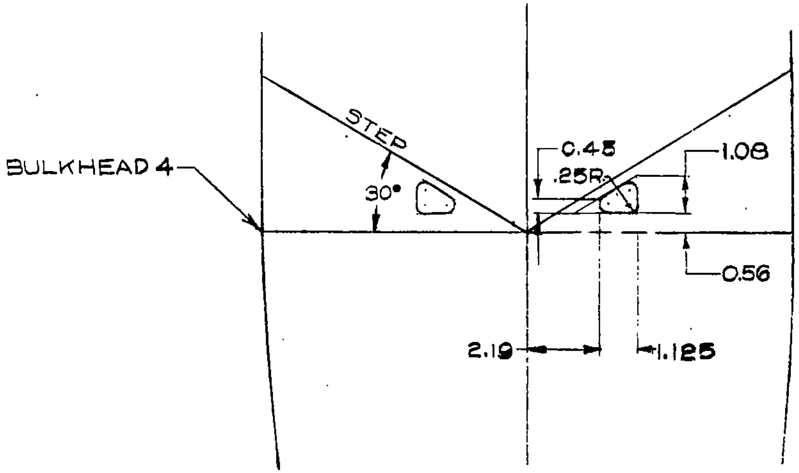
NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

MODEL STEP PROFILE



MODEL VENTILATION OPENINGS

TOTAL AREA = 1.32 SQ.IN.



PRODUCTION VENTILATION OPENINGS

TOTAL AREA = 1.66 SQ. IN.

FIGURE 2.- MODEL 131 DETAILS OF STEP AND VENTILATION OPENINGS.

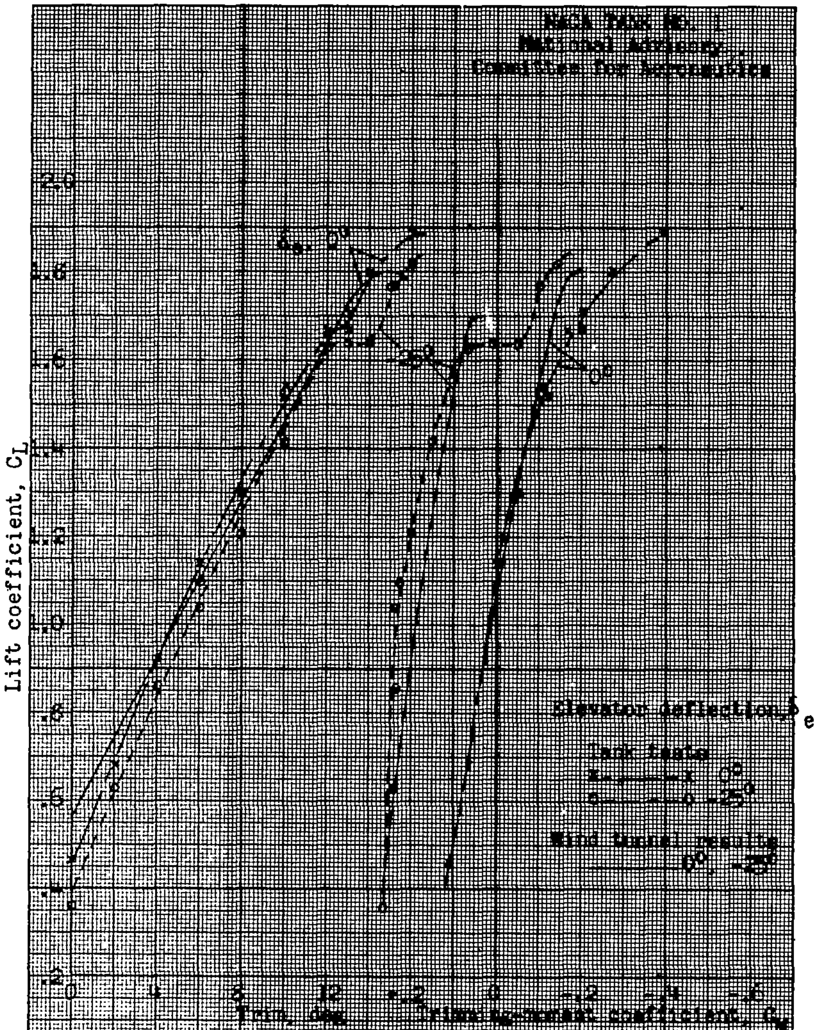


Figure 3.- Model 131. Power off. Flaps 20°. Stabilizer -2° to R.L. Normal chord elevators.

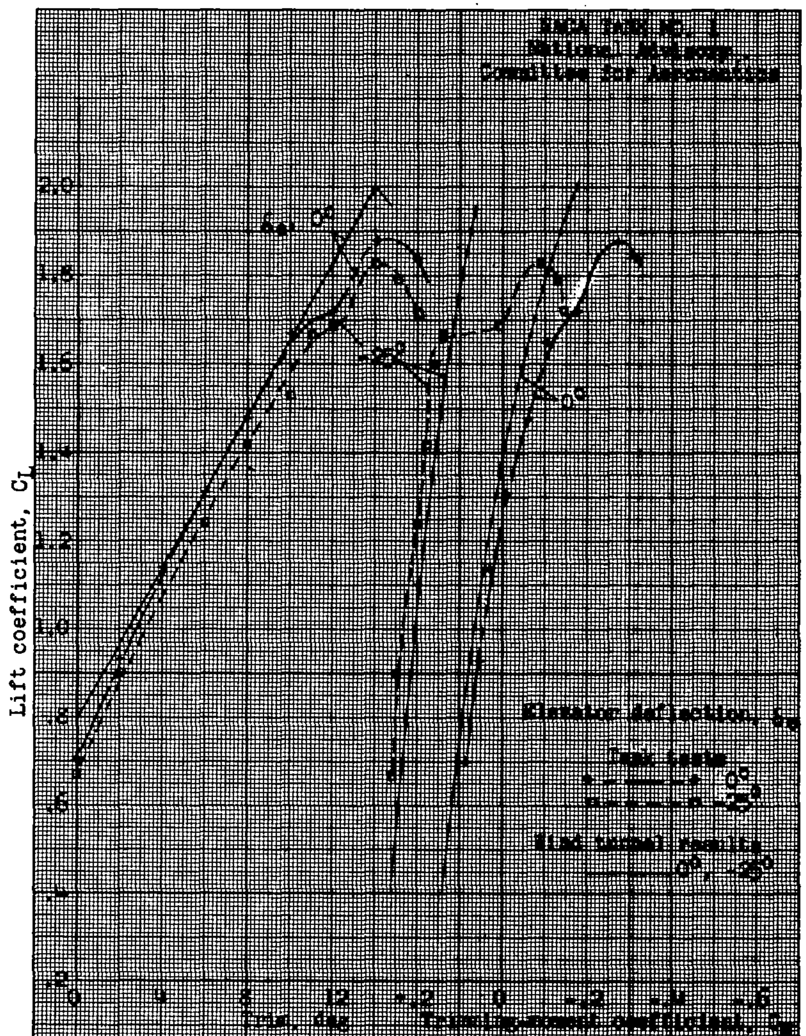


Figure 4.- Model 131. Power off. Flaps [illegible]. Stabilizer -3° to R.L. Normal chord elevators.

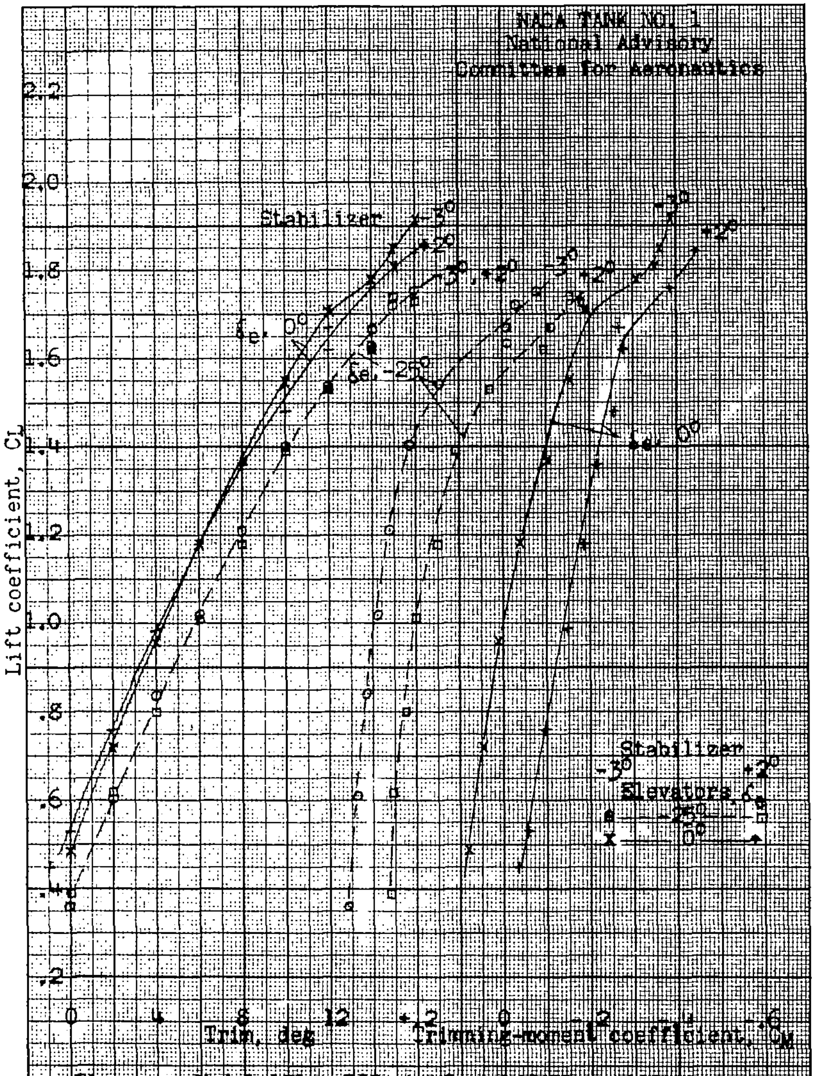


Figure 5.-Model 131. Effect of stabilizer setting, power off, flaps 20°. Increased chord elevators.

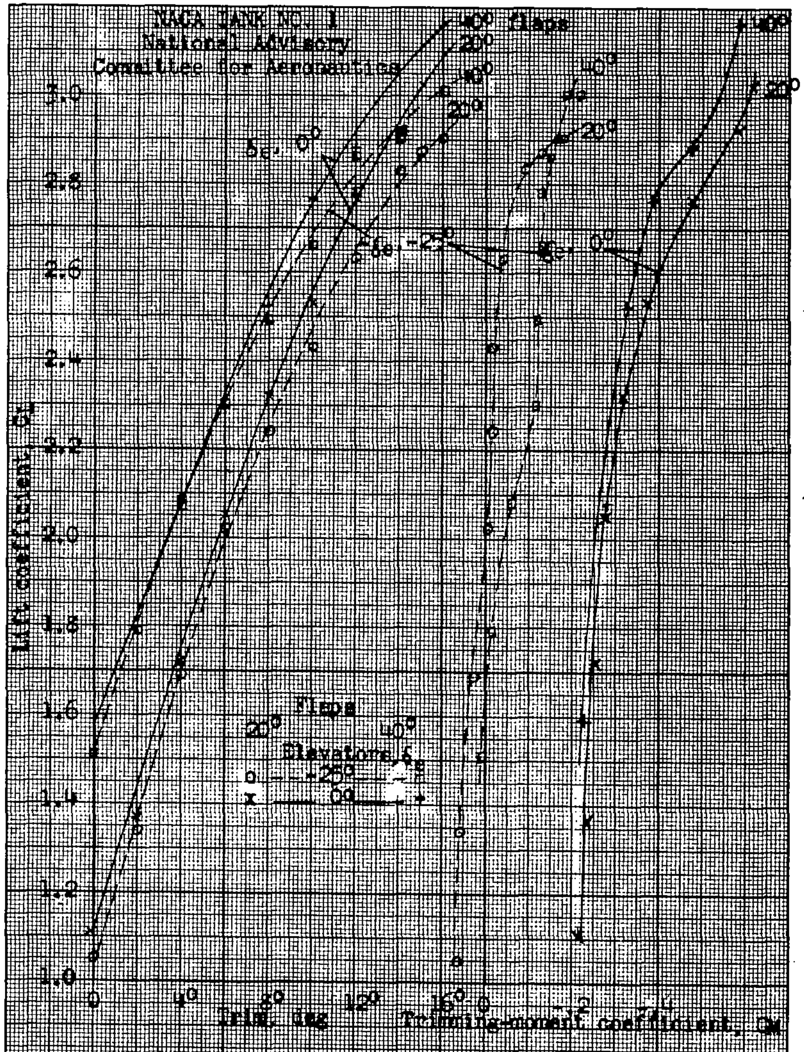


Figure 6.-Model 131. Propeller rpm 7000, stabilizer +2° to S.L. Increased chord elevators.

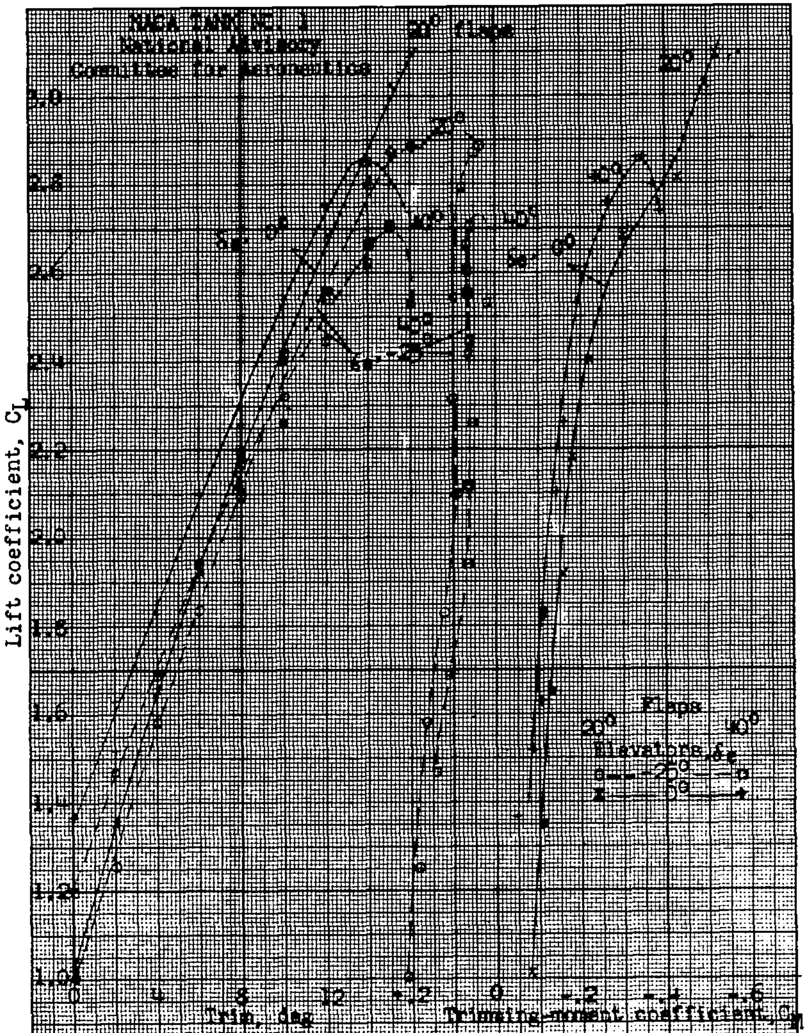


Figure 7.- Model 131. Propeller rpm 6000. Stabilizer -3° to S.L. Increased chord elevators.

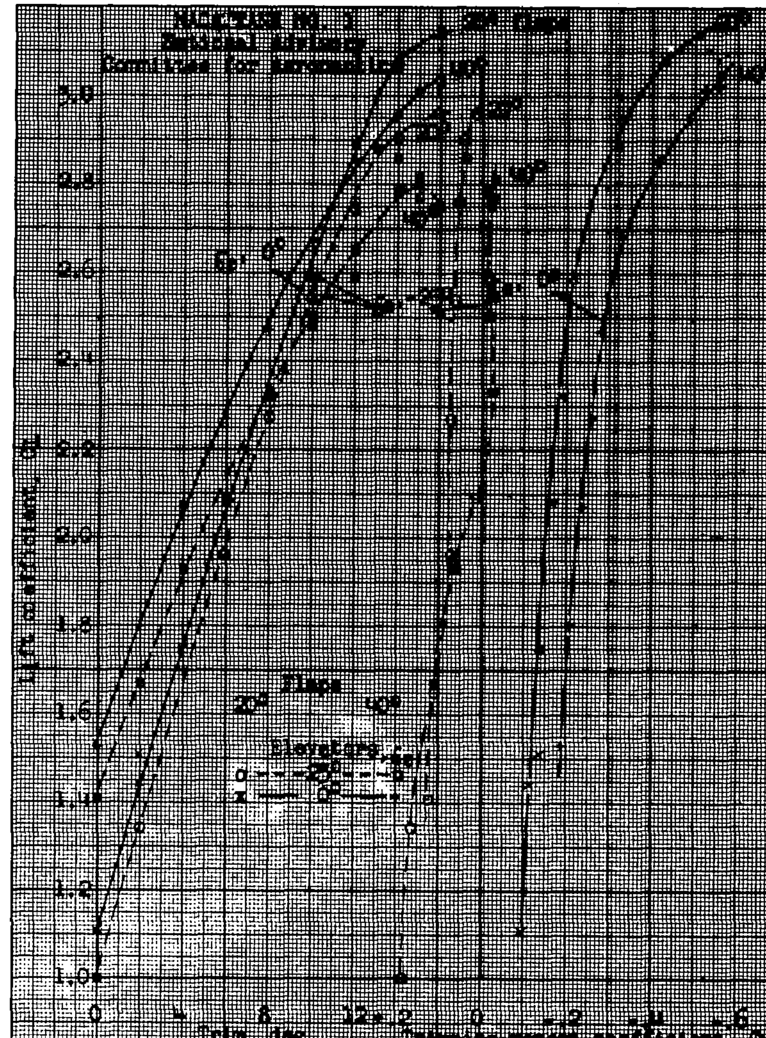


Figure 8.- Model 131. Propeller RPM 7000. Stabilizer -3° to S.L. Increased chord elevators.

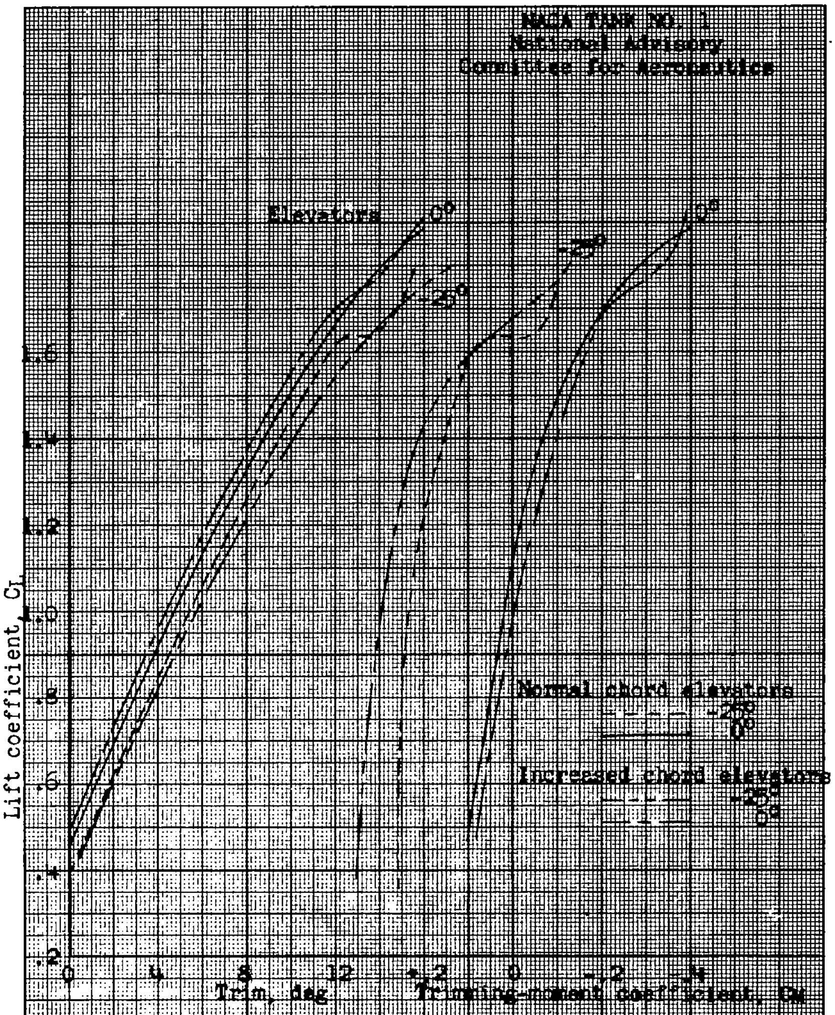


Figure 9.-Model 131. Effect of increased chord elevators, power off, stabilizer -3° to B.L. Flaps 20°.

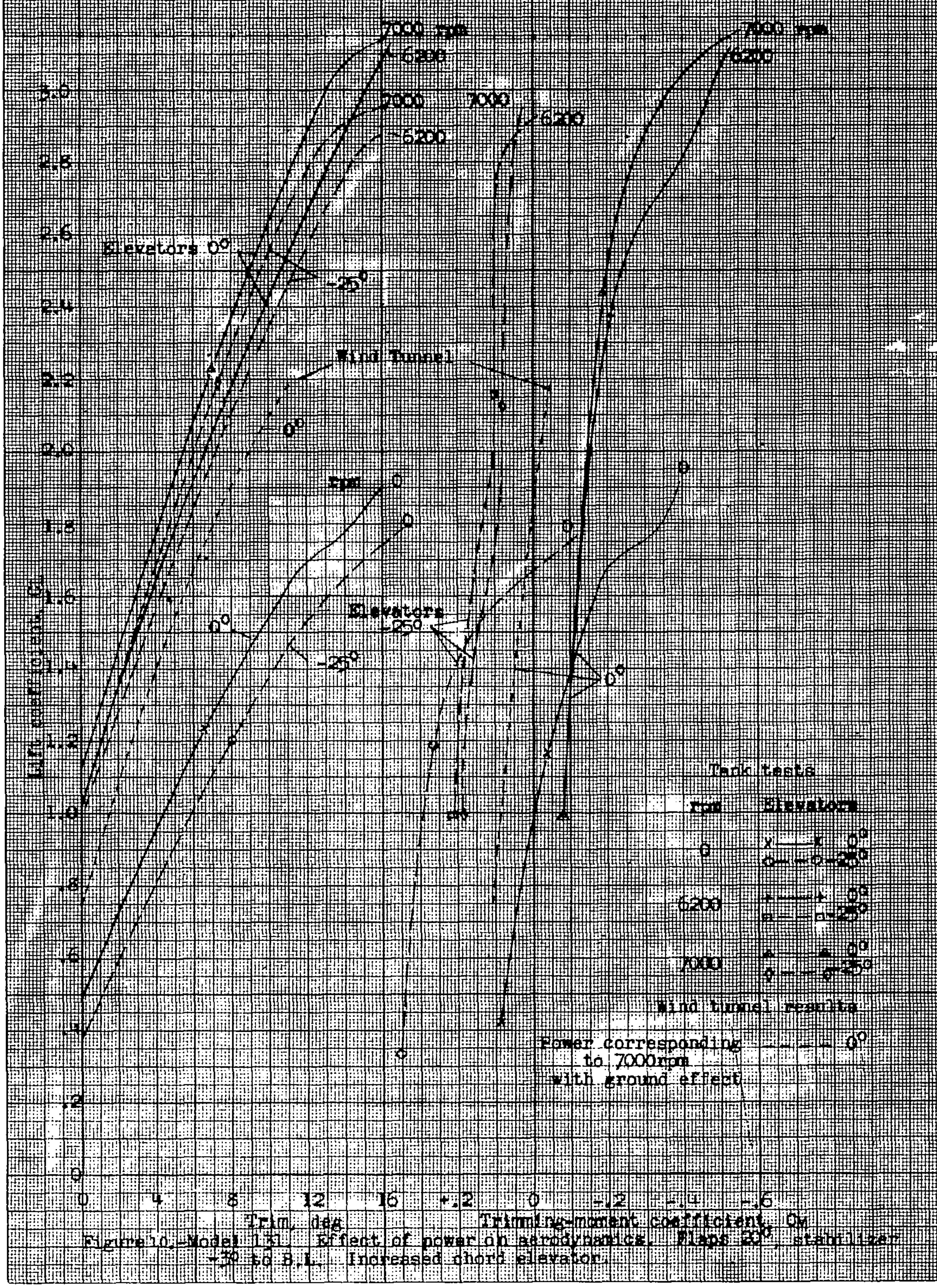


Figure 10.-Model 131. Effect of power on aerodynamics. Flaps 20°, stabilizer +3° to B.L. Increased chord elevator.

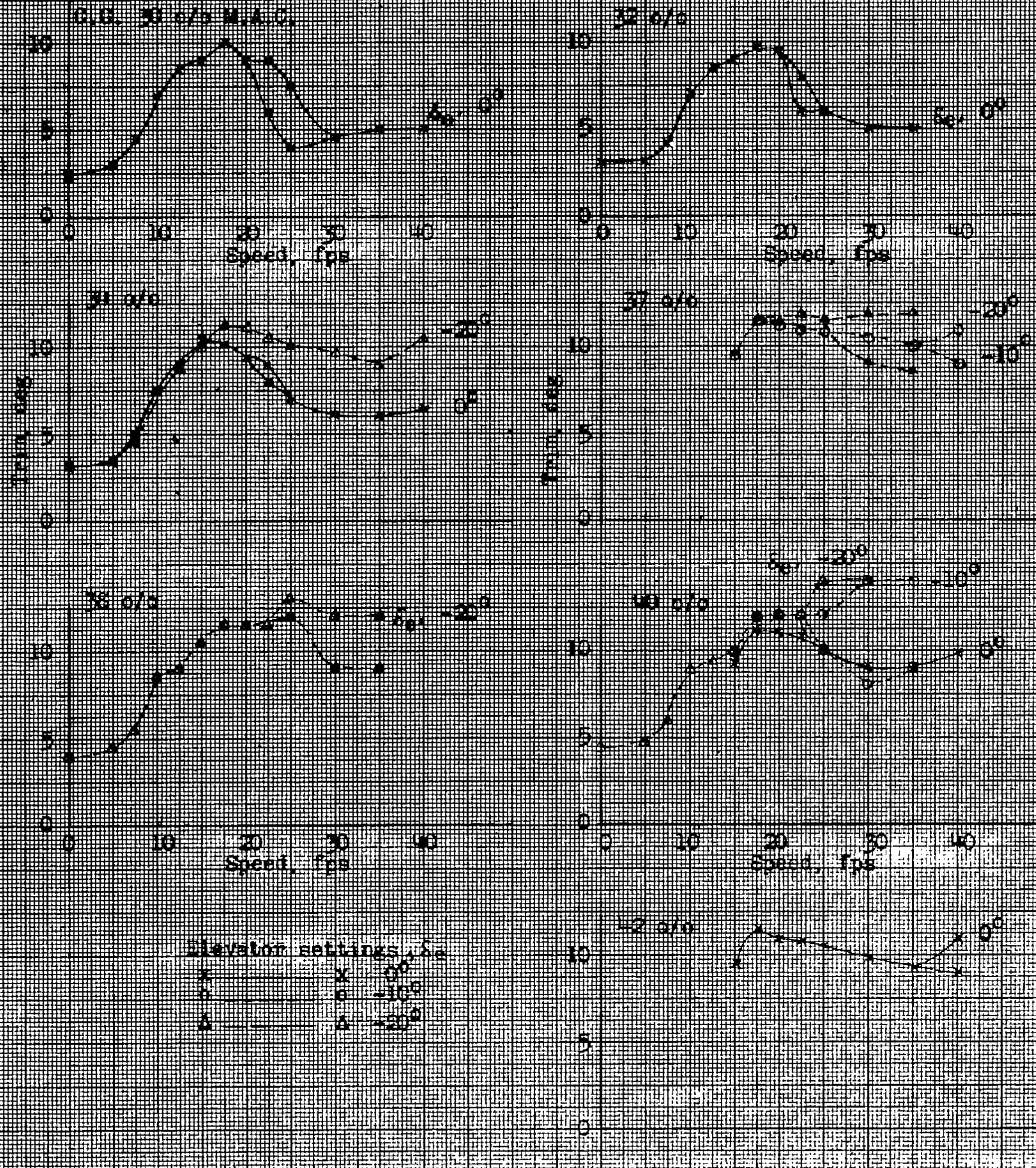


Figure 11a.- Model 131. Variation of trim with speed; propeller rpm 6200; flaps 20°; Δ_o = 148 lb (76,000 lb full-size).

L-688

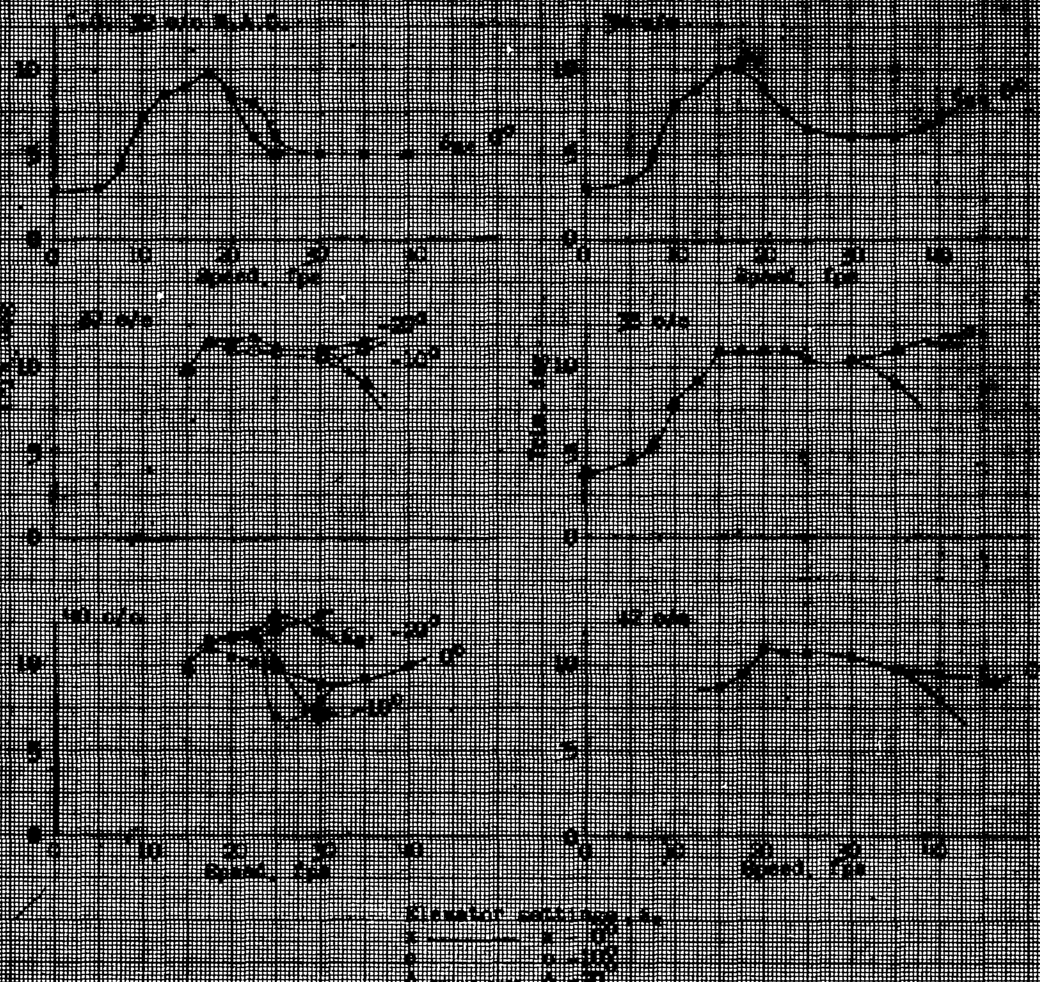


Figure [illegible].– Model 131. Variation of trim with speed; propeller rpm 5200; flaps 20°, Δ_0 = 140 lb (72,000 lb full-size).

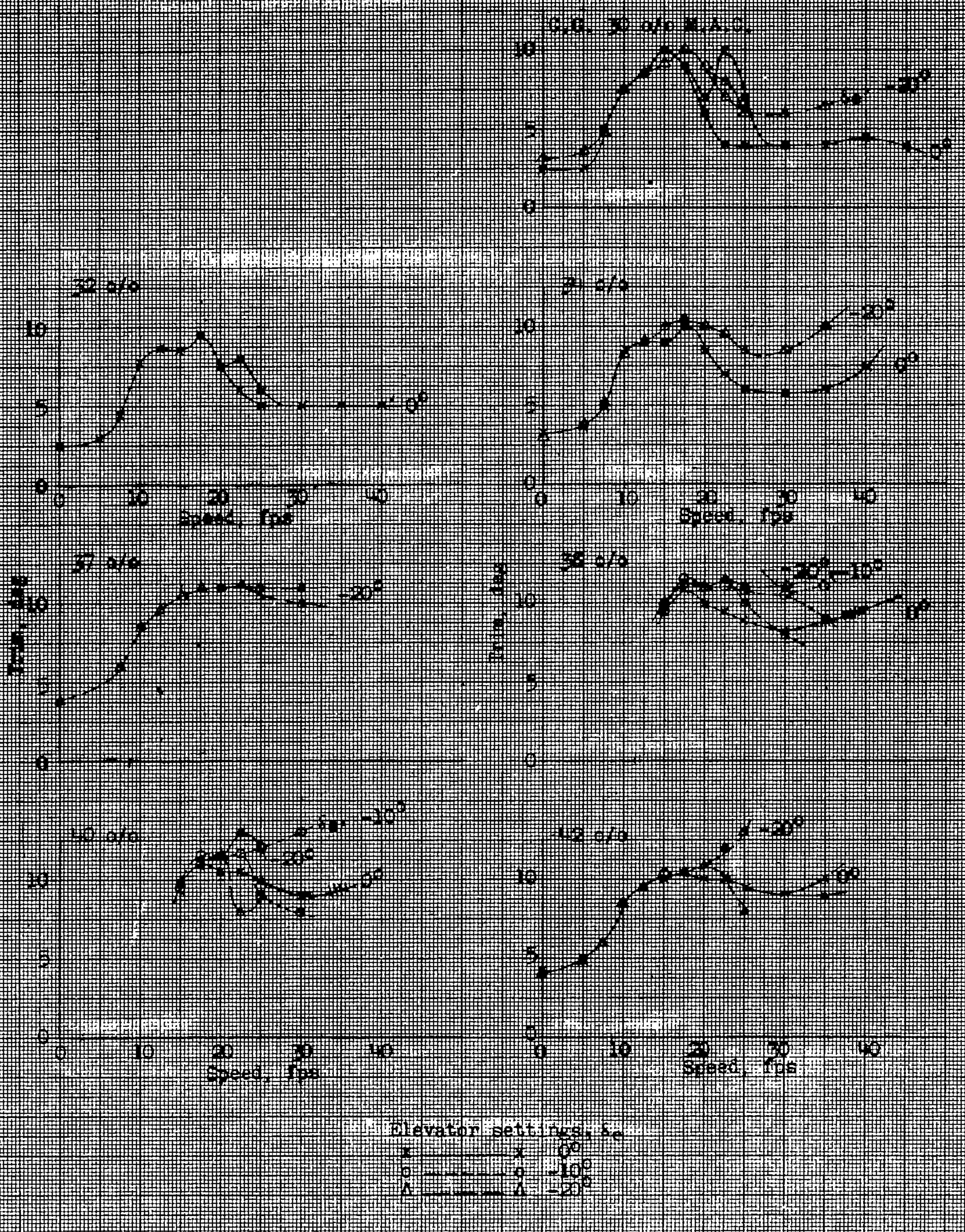


Figure [illegible].- Model [illegible]. Variation of trim with speed; propeller rpm 6200; flaps 20°; Δ_o = 135.6 lb (70,000 lb full-size).

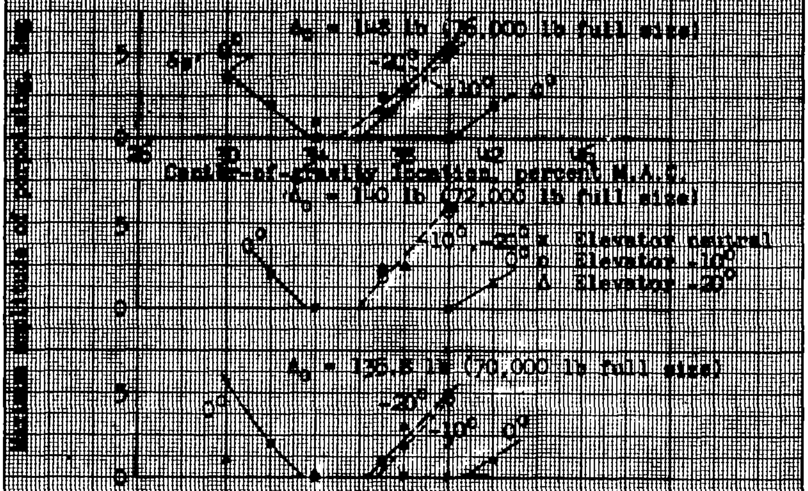


Figure 12. - Model 131. Variation of maximum amplitude of porpoising with center-of-gravity location at various loads and elevator settings. 6200 rpm, flaps 20°.

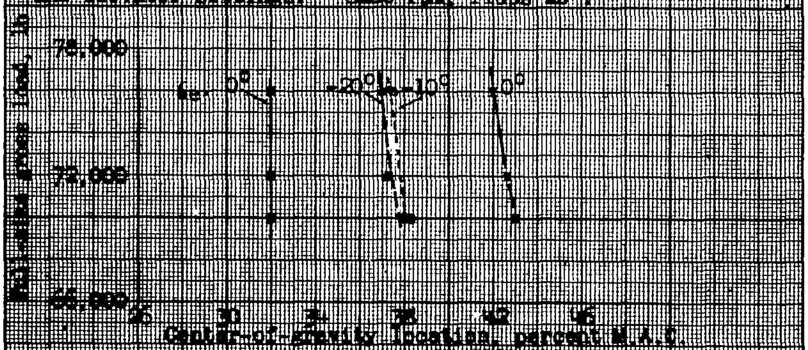


Figure 13. - Model 131. Variation of stable range of centers of gravity with gross load and elevator deflection. 6200 rpm, flaps 20°.

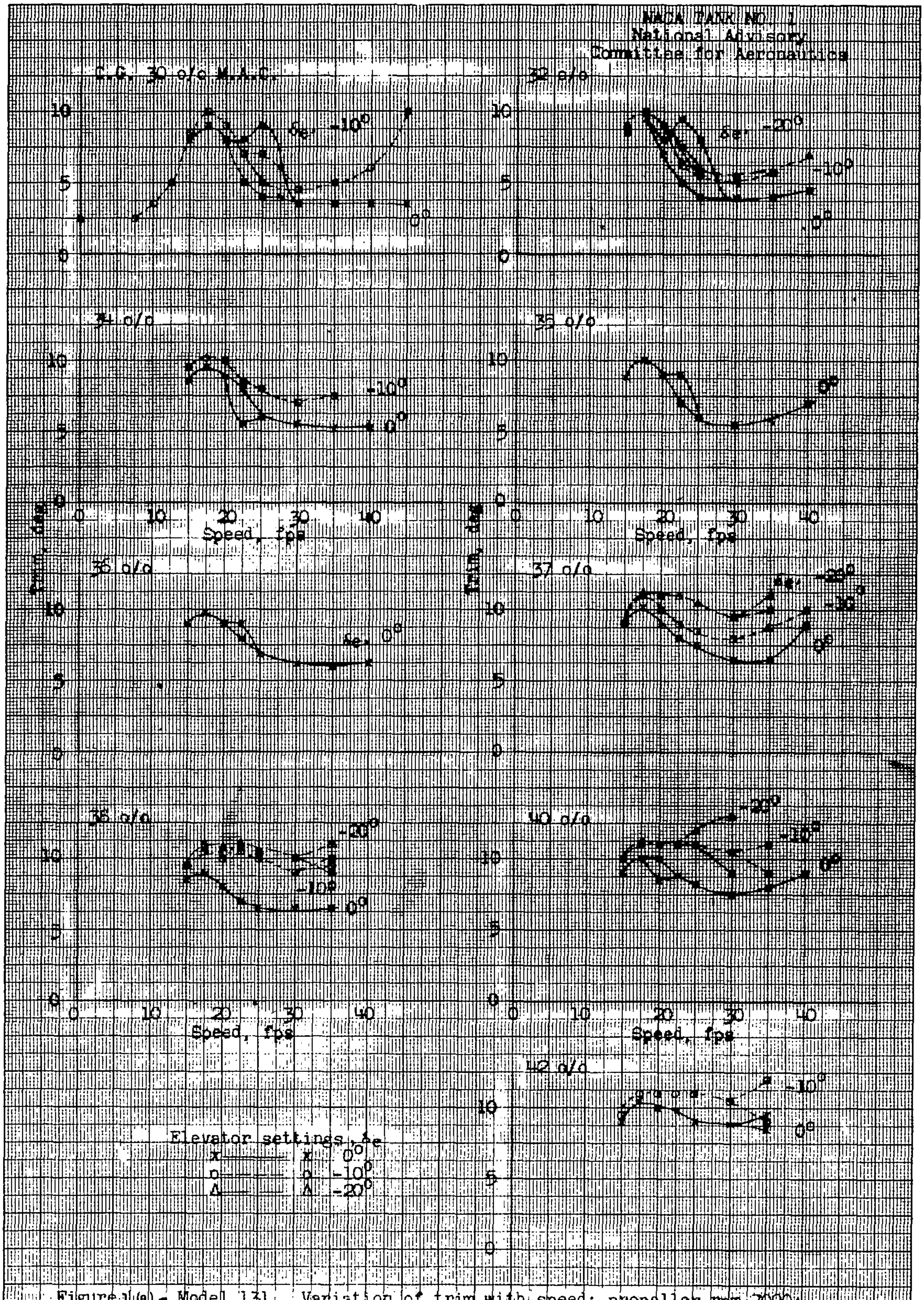


Figure 14(a).- Model 131. Variation of trim with speed; propeller rpm 7000; flaps 20°; Δ_o = 148 lb (76,000 lb full-size).

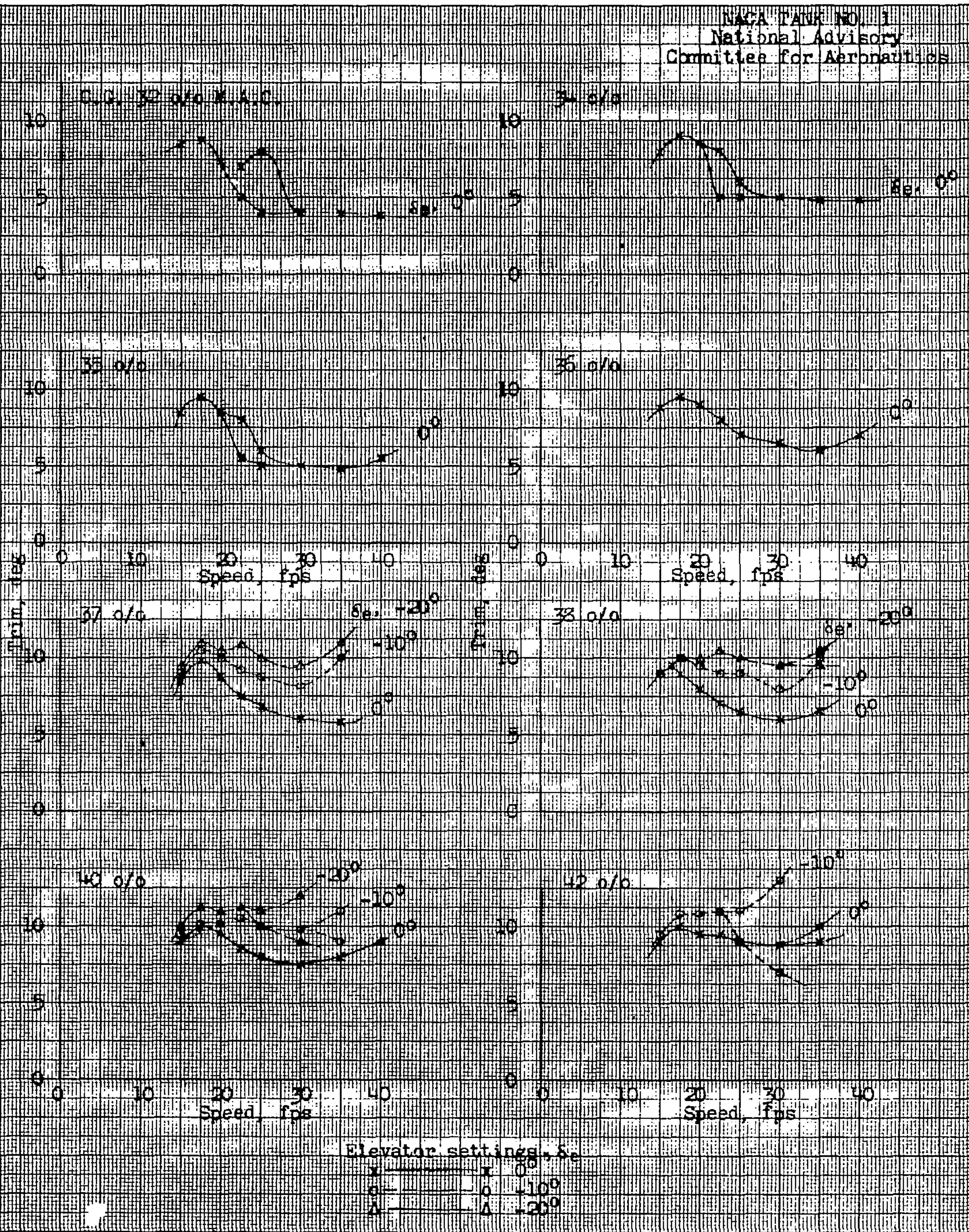


Figure 14a. - Model 131. Variation of trim with speed; propeller rpm 7000; flaps 20°; Δ_0 = 140 lb (72,000 lb full-size).

NACA TANK NO. 1
National Advisory
Committee for Aeronautics

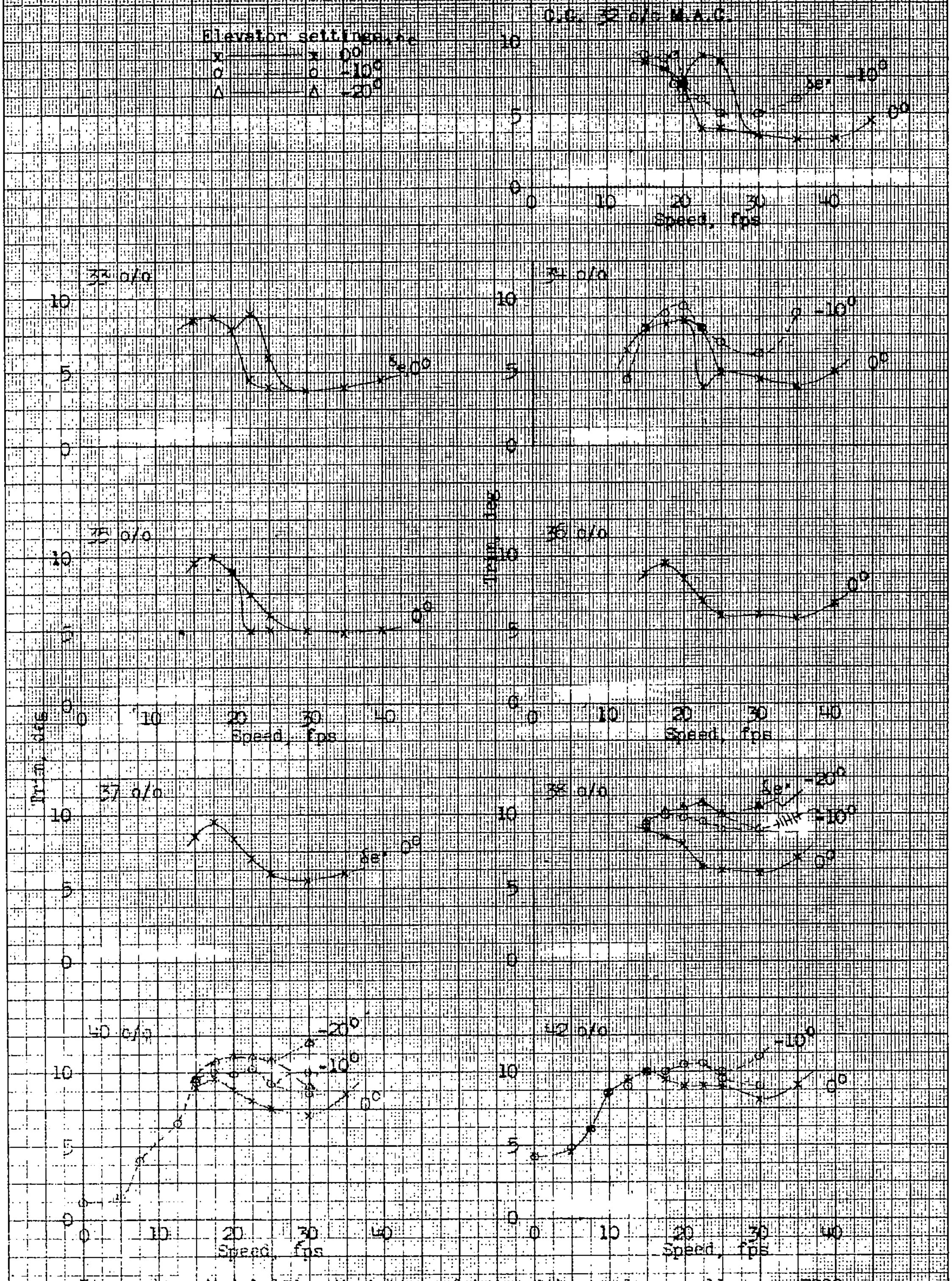


Figure 11c. - Model 131. Variation of trim with speed; propeller rpm 7000; flaps 20°; Δ_0 = 135.8 lb (70,000 lb full-size).

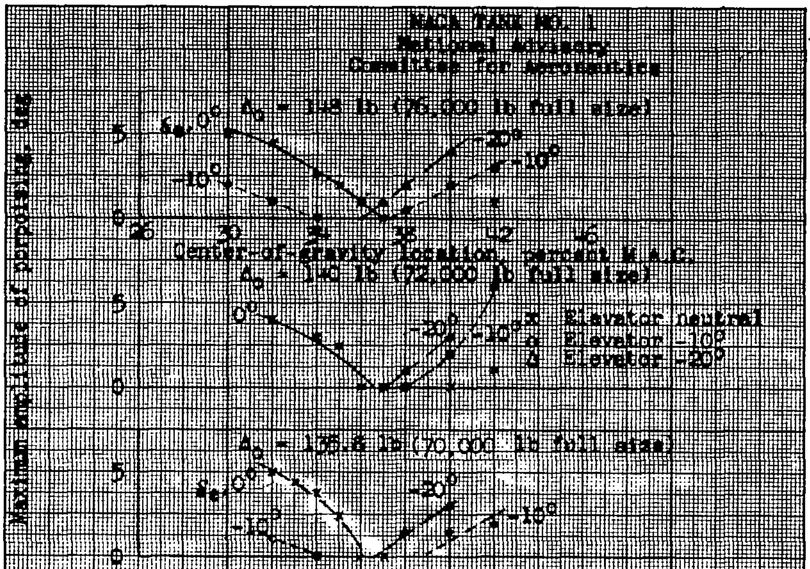


Figure 15. - Model 131. Variation of maximum amplitude of porpoising with center-of-gravity location at various loads and elevator settings. 7000 rpm, flaps 20°.

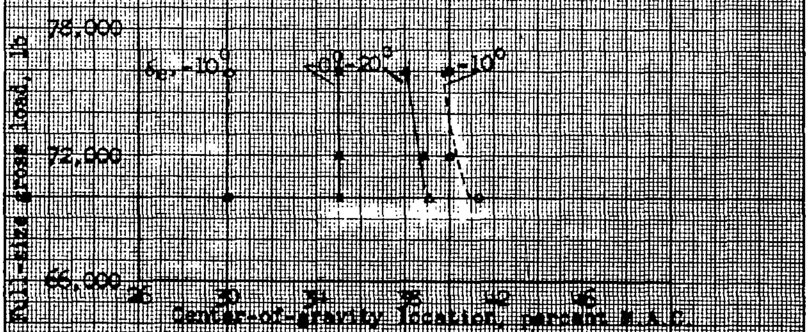


Figure 16. - Model 131. Variation of stable range of centers of gravity with gross load and elevator deflection. 7000 rpm, flaps 20°.

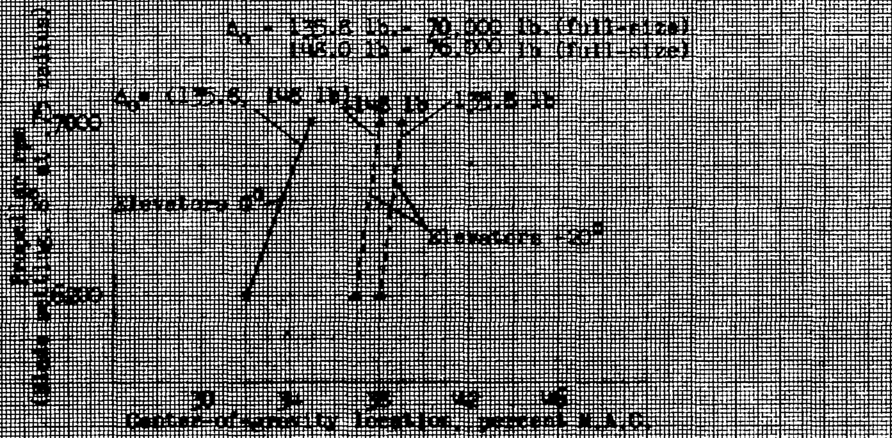


Figure 17.- Model 131. Variation of stable range of centers of gravity with propeller rpm and gross load. Flaps 20°.

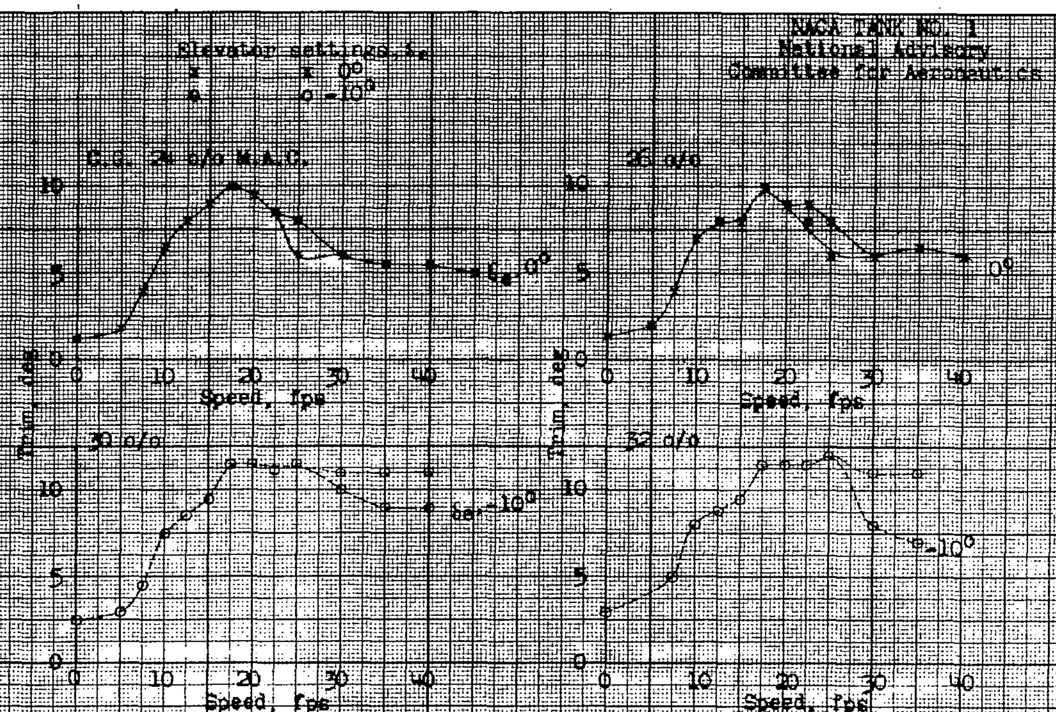


Figure 18a.- Model 131. Variation of trim with speeds: rpm 7000; flaps 0°; Δ_0 = 148 lb (75,000 lb full-size).

NACA TN No. 1
National Advisory
Committee for Aeronautics

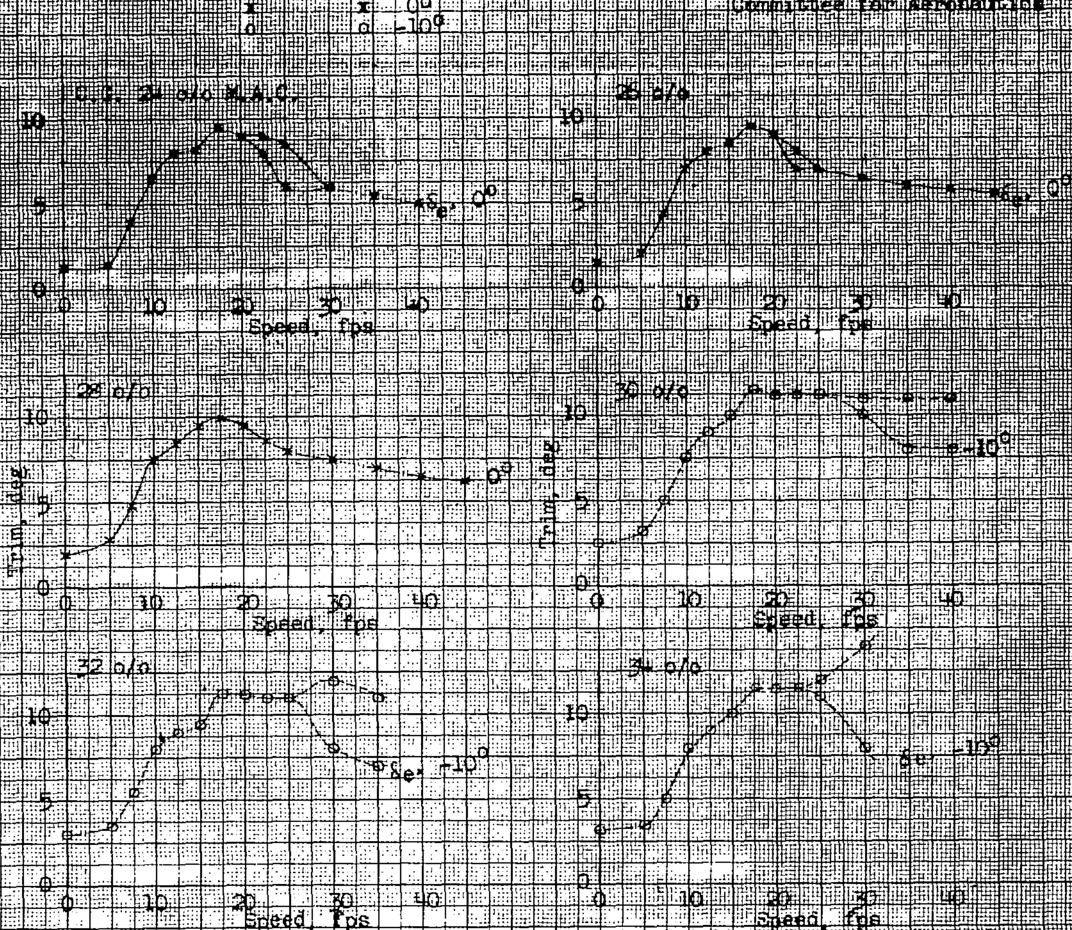


Figure 18.- Model 131. Variation of trim with speed; propeller rpm 7000; flaps 0°; Δ_0 = 135.8 lb (70,000 lb full-size).

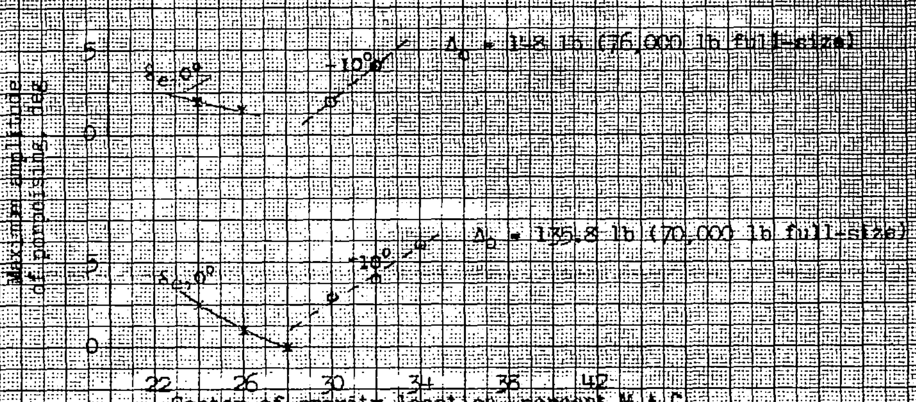


Figure 19.- Model 131. Variation of maximum amplitudes of porpoising with center-of-gravity location at various loads and elevator settings; rpm 7000; flaps 0°.

NACA TANK NO. 1
National Advisory
Committee for Aeronautics

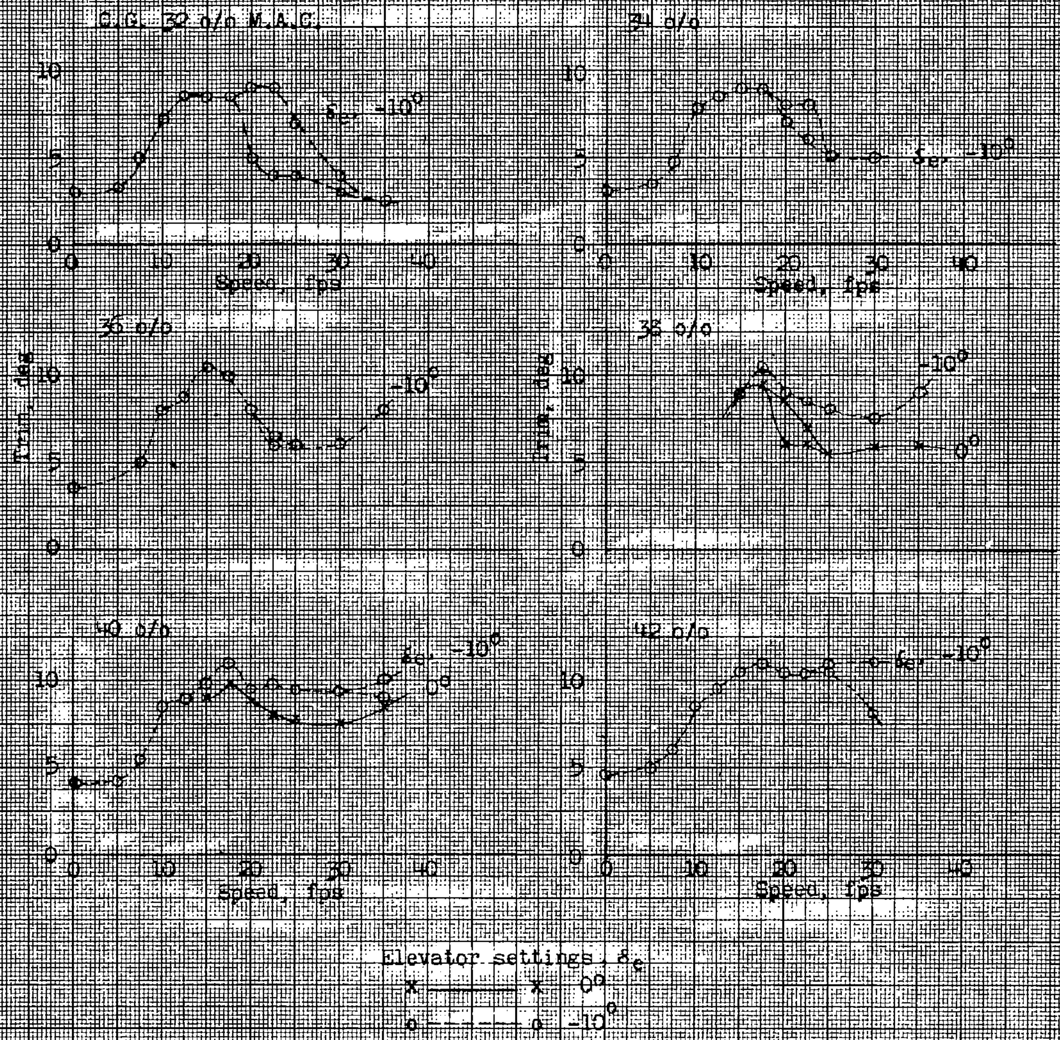


Figure 24a.- Model 131, Variation of trim with speed, propeller rpm 7000, flaps 40°; Δ_0 = 148 lb (76,000 lb full-size).

NACA TANK NO. 1
National Advisory
Committee for Aeronautics

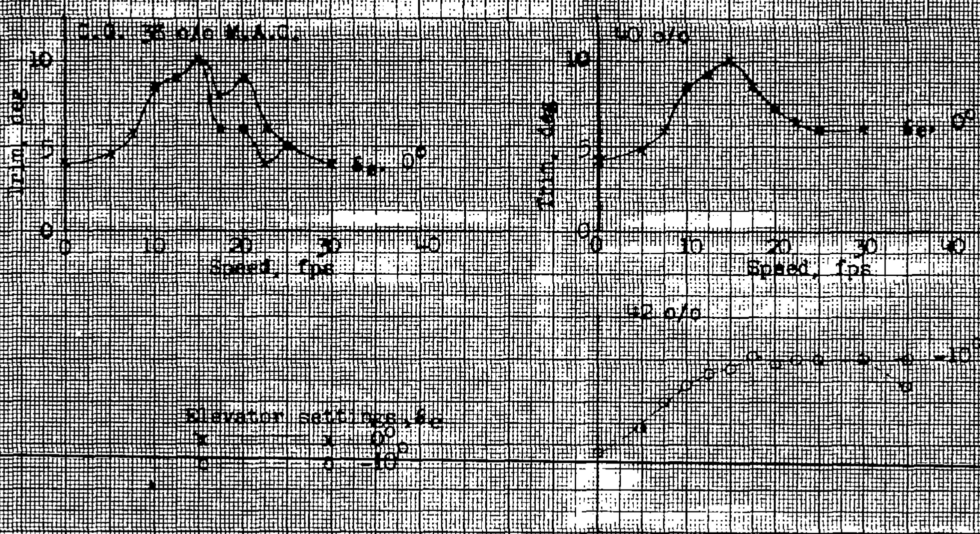


Figure 20. - Model 131. Variation of trim with speed; propeller rpm 7000; flaps 40°; Δ_o = 135.8 lb (70,000 lb full-size).

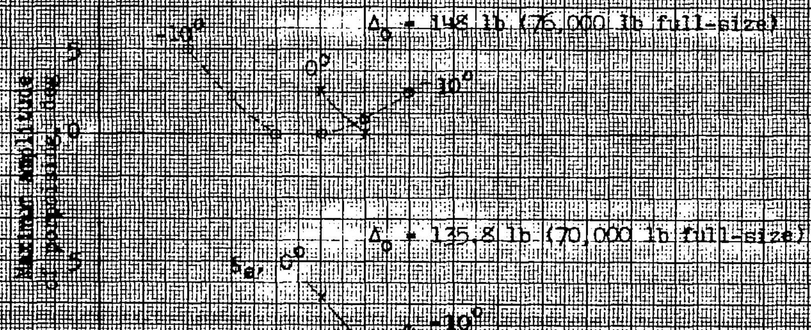


Figure 21. - Model 131. Variation of maximum amplitudes of porpoising with center-of-gravity location at various loads and elevator settings; rpm 7000; flaps 40°.

NACA TASK NO. 1
National Advisory
Committee for Aeronautics

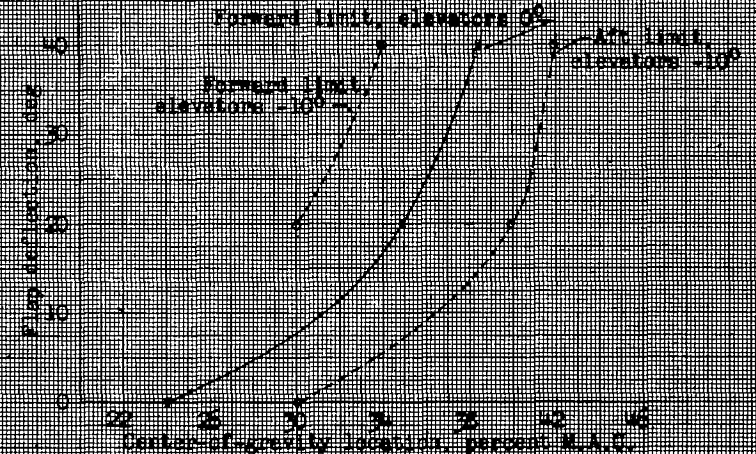


Figure 22.- Model 131. Effect of flap deflection on the stable range of center of gravity. Δ_0 = 146 lb (176,000 lb full-size). Propeller rpm 2000.

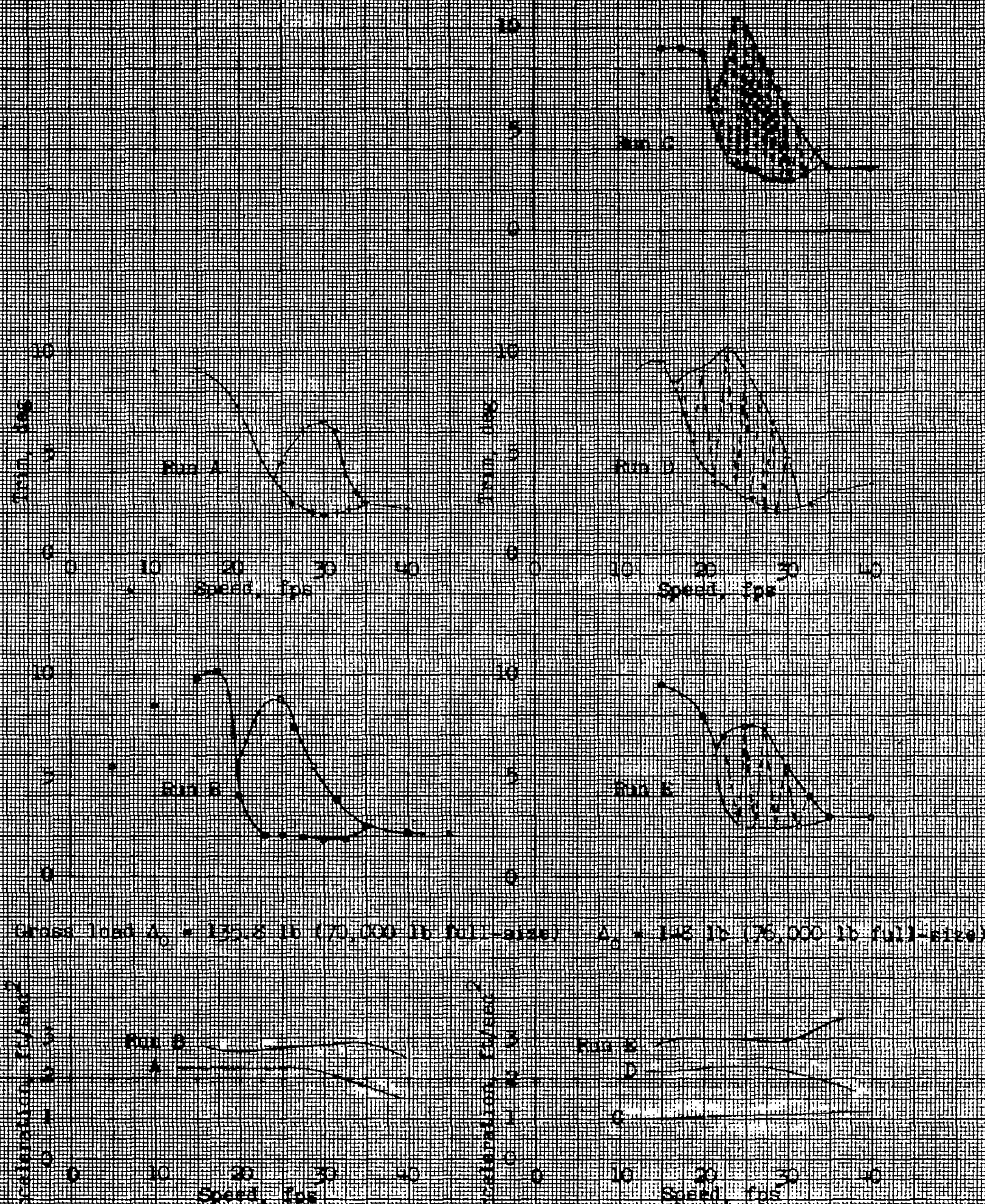


Figure 24a.- Model 131. Variation of trim with speed at different accelerations. Center of gravity at 30 o/o M.A.C. Elevators neutral. Flaps 20°, propeller rpm 7000.

NACA TANK NO. 1
National Advisory
Committee for Aeronautics

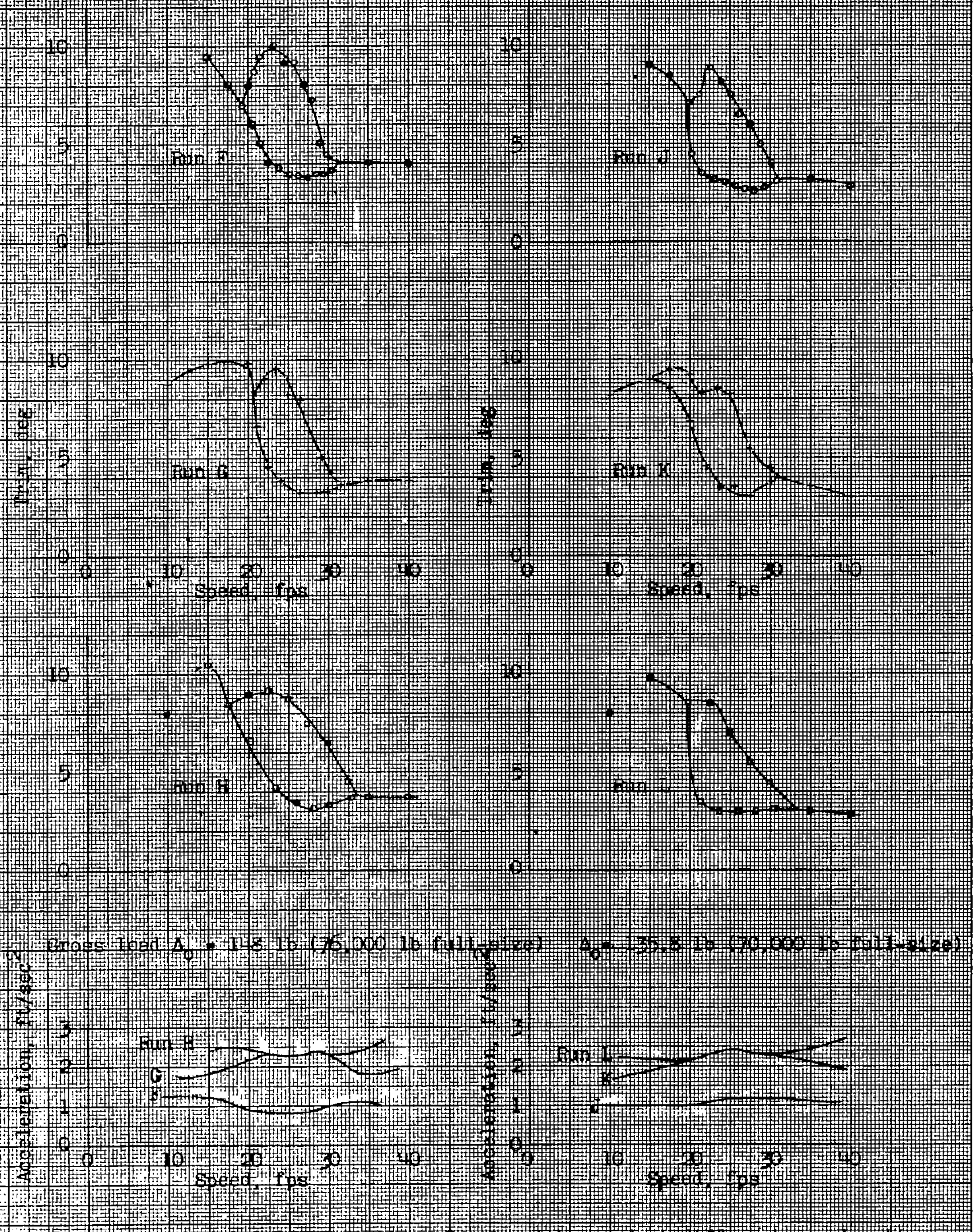


Figure 30.- Model 131. Variation of trim with speed at different accelerations. Center of gravity at 32 c/o M.A.C. Elevators neutral. Flaps 20°; propeller rpm 7000.

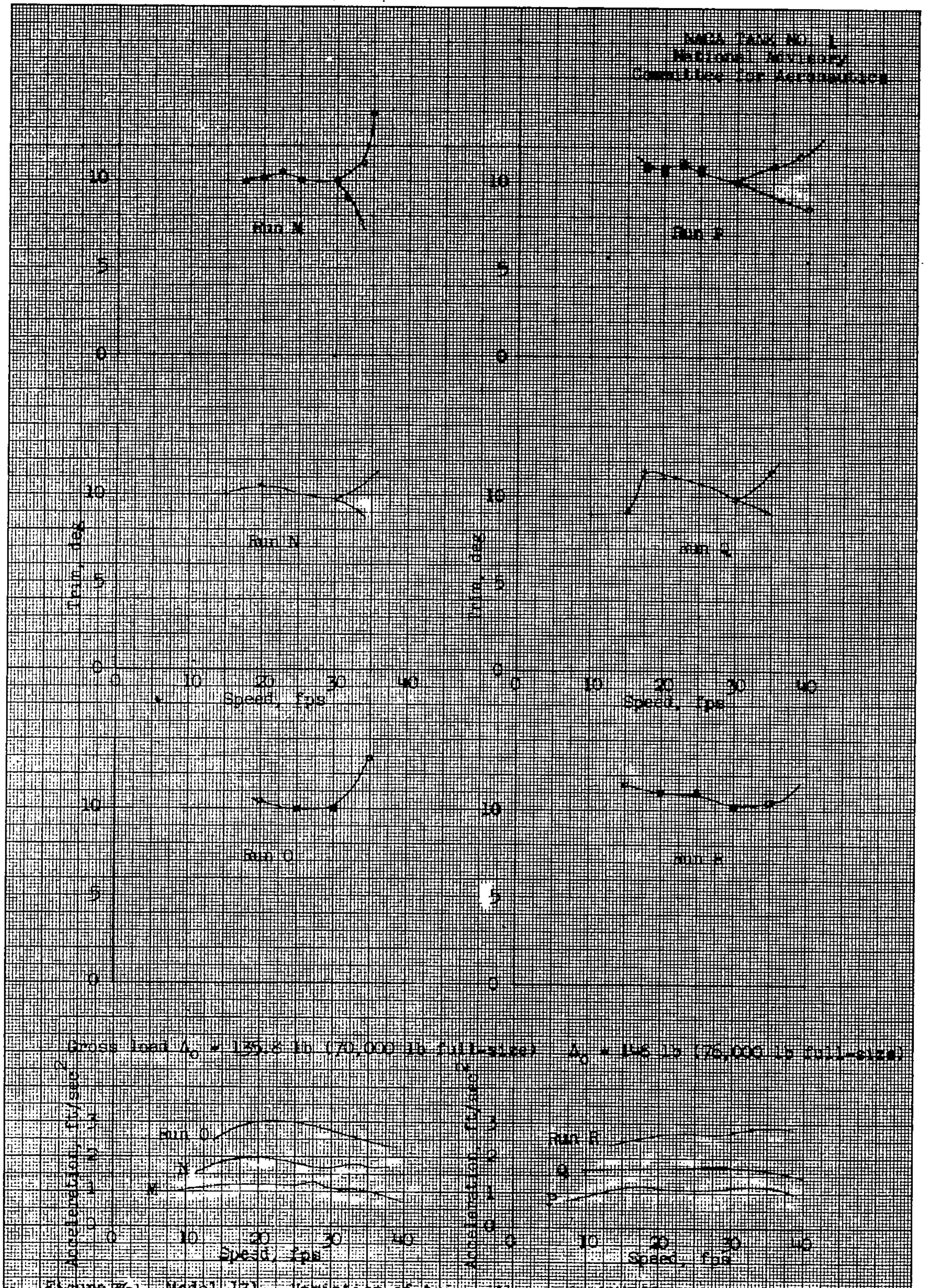


Figure 9(c).- Model 131. Variation of trim with speed at different accelerations. Center of gravity at 40 o/o M.A.C. Elevators -20°. Flaps 20°, propeller rpm 7000.

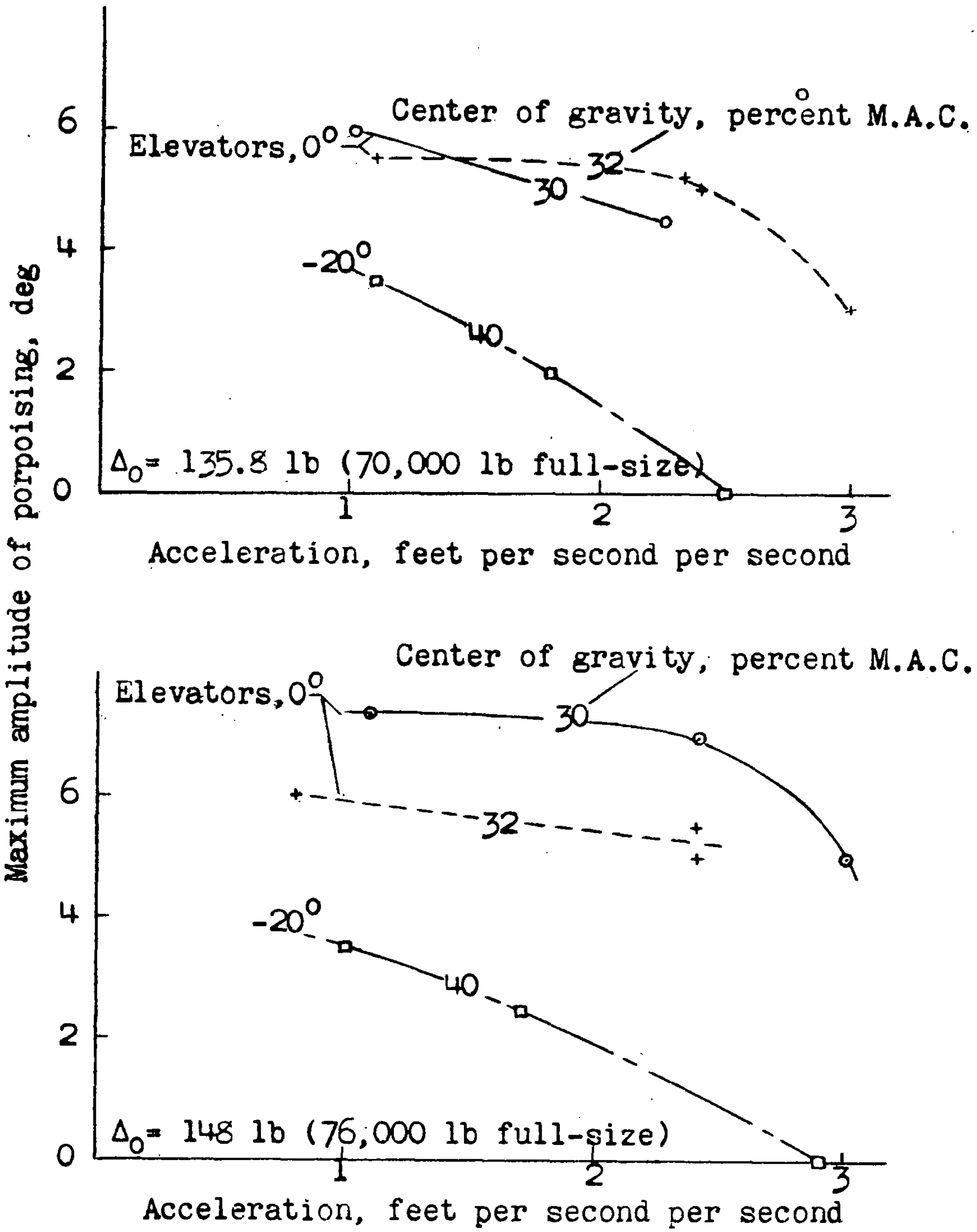


Figure 24.- Model 131. Variation of maximum amplitude of porpoising with acceleration for different positions of the center of gravity. Flaps 20°. Propeller rpm 7000.

NASA Technical Library
3 1176 01403 5746